Chapter

Application Technologies for Functional Finishing of Textile Materials

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Abstract

Nowadays, the primary energy resources and existing water reserves in the world are gradually decreasing. Because of global warming and high consumption of energy and water, researches have focused on new technologies and methods which aim of optimum use of resources while applying functionalites to the material. When the energy and water consumption of industries is examined, it could be obviously determined that the textile industry is seen to be at a substantial level. For this reason, in this chapter broad information of application systems including conventional and low-liquor application techniques with updated versions which show notable improvements in textile industry lately, have been detailed in a way of properties, parameters and running mechanisms on textile materials.

Keywords: low-liquor application, energy, water, finishing, application, textile

1. Introduction

Today, consumption of fossil fuels is dramatically increasing along with improvements of life such as industrialization processes with the increase of the world population. It has long been recognized that this excessive fossil fuel consumption not only leads to an increase in the rate of diminishing fossil fuel reserves, but it also has a significant adverse impact on the environment, resulting in increased health risks and the threat of global climate change [1]. The potentially most important environmental problem relating to energy and water resources is global climate change (global warming or the greenhouse effect). The increasing concentration of greenhouse gases such as carbon dioxide, methane, chlorofluorocarbons, halons, nitrous oxide, ozone, and peroxyacetylnitrate in the atmosphere is acting to trap heat radiated from Earth's surface and is raising the surface temperature of Earth [2]. This climate change has an increasingly negative impact on water resources; causing a serious decrease in available water reserves in the world [3]. In order to solve this problem, researchers have been focused on new methods for optimum use of resources with new technologies which save energy and reduce water consumption.

When the energy consumption in textile enterprises are compared to other branches of industry, it can be seen that the textile industry is seen to be at a substantial level. It could also be note that finishing departments are the most energy consuming ones among the other parts of textile manufactories. 45–75% of the energy consumed in finishing departments is listed as wet processes, 15–40% for drying and fixing processes, 8–18% for other processes and ventilation. Electricity consumption is not much in finishing departments; however, heat energy and water consumption is at very high level [4, 5]. For this reason, energy and water-saving technologies play an important role in the machines and application methods used in finishing processes.

Although textile finishing processes can be applied in different material forms (fiber, tops, yarn, fabric etc.), the most common is fabric finishing. General expectations for all these finishing are having homogenous effect, non-damaged fibers, non-broken fabric, repeatable and economical process, low environmental impact and reduced energy and water consumption. Different application techniques are used in the studies related to give desired properties to textile materials. Most of these application techniques are wet processes. These wet processes include exhaustion, impregnation, vacuum application, maximum application techniques as well as spraying, coating, transfer and foam application methods which are among the low-liquor application techniques [6]. In addition to these methods, microencapsulation, plasma application, sol–gel technology and lamination techniques, which have become increasingly important in recent years, are also included in finishing applications.

Nowadays, the methods and techniques used in the textile industry are desired to be environmentally-friendly and to save water and energy besides the other requirements such as functionality, durability, repeatability and being cost-effective. With the increase of diversification of today's industrial requirements, one functionality on the fabric may be insufficient to meet these requirements, therefore, although it varies according to area of utilization, being multifunctionality becomes more of an issue. In some cases, the fact that the fabric has more than one functionality on the whole surface entirely, regardless of front or back sides of the material, causes an increase in cost unnecessarily and also prevents showing sufficient efficiency in the area of use. For instance; for a sportswear outfit, the interior structure of the fabric is desired to be hydrophilic to absorb the sweat and water occurred during movement of the body, while the outer structure of the material is expected to water–oil-soil repellent. If the water repellency functionality is applied to the entire fabric, water repellant chemicals will act functional on the outer side of the fabric while it will serve as blocking barriers by preventing the absorption of sweat and water in the interior side of the material. This will not only bring on difficulties in use but also cause increased unnecessary cost during the finishing process of the material.

Since the conventional padding application methods, which are still in use widely today, do not allow the transfer of different chemicals to different sides, both sides of the fabric are treated with the same chemical substance and due to unnecessary material transfer, both the expected requirements cannot be fully met and cause an increase in costs. For this reason, it has emerged that some functionality needs to be applied to a single surface of the fabric.

Providing multifunctionality in a single-bath could have disadvantages in many respects that all the requested functionalities are mixed with each other in a single recipe and in the same bath. The first of these disadvantages is that all basic and auxiliary chemicals used in the same bath, belonging to different functionalities, may not be compatible with each other. Since the chemical structures of materials belonging to different functionalities are different, their mechanism of action is also different, and therefore problems may be encountered in providing a homogeneous mixture. The second of these disadvantages is that since all the chemicals are mixed with each other, the functionalities will be given in a mixed order regardless of the back or front face of the fabric, unfavorable functionality may be occurred on the undesired side or the requested efficiency is not achieved as expected or no functionality is obtained at a sufficient level. Therefore, due to all these problems and requirements, achieving multifunctionality by transferring more than one functionality to the same and/or different sides of the fabric in an effective and permanent way in accordance with the field of use has become a necessity both in industrial and academic terms.

There is a way of combining fabric layers with different functionalities by lamination methods or so, for obtaining multifunctionality, but because of each separate layer has own functionality, the endproduct takes up more space in terms of volume and increases the cost of the material. For this reason, multifunctionality in single-layer fabrics should be carried out by considering the requirements of providing mobility to the user, being useful and flexible, and saving in material costs.

Due to all the above-mentioned requirements in textile industries; advantages and disadvantages of existing conventional methods besides new generation finishing processes which focuses on reducing water and energy consumption mostly, are defined in this chapter.

2. Wet finishing processes

Most of the textile finishing application techniques are wet processes. These wet processes can be listed as follows: exhausting process, impregnation, coating, transfer, spraying and foam application. It should be noted there is an optimum level of liquor application which is just high enough to ensure adequate distribution of the chemicals within the fabric. This critical add-on value (CAV) depends on fiber type, fabric construction and fabric pretreatment [6–11]. The wet processes have been in use for a long time however; they have been updated in many ways nowadays; such as using new technologies in impregnation machines with lower wet pick-up ratios, providing homogenous application in new version of chemical foam application, removing the blockage occurred in nozzles of spraying machines. Minimum application methods, which focuses on reducing water and energy consumption, have an increased importance recently in finishing processes with a wide range of functionalities provided such as water–oil-soil repellency, flame retardancy, antibacterial efficiency and so many other functionalities due to their significant advantages over conventional methods. The application technologies including conventional ones and updated low-add-on finishing applications have been detailed in this review.

2.1 Exhausting process

The essence of the application with the exhaustion method is that the product to be treated is in wet-process for a long time at the long liquor ratio. The liquor ratio in the studies according to the exhaustion method is in the range of 1:2–1:100. This method is also called full bath method or discontinue method. The fabric to be treated is placed in a bath and allowed to absorb the finishing agent from the bath until a chemical-balance is reached between the finishing agent on the fiber and the one in the bath. In order to provide sufficient and economical results in this method, it is essential that the finishing material used has an affinity towards the textile material. In other words, the finishing material dissolved or homogeneously dispersed in the bath should have a high desire to be withdrawn from the bath by the fibers.

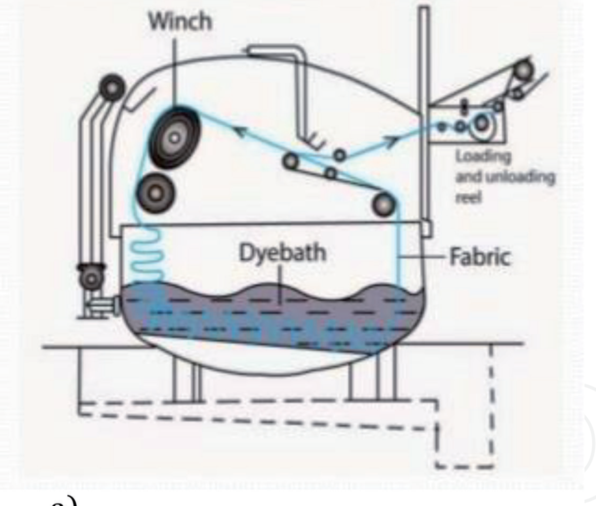
Dyeing process can be carried out with textile fibers, yarns, fabrics or garments. However, there are reasons for dyeing different fiber forms. Fiber dyeing is used as a styling technique; natural fibers or staple synthetics are dyed in bundles or baskets. Dope or solution dyeing is the process where color is mixed into the polymer solution prior to fiber extrusion. Certain synthetics fibers such as polyethylene can only be colored using this technique. Yarn dyeing which is also a styling technique, is used to produce stripes, plaids, and some complex designs with 100% fiber content products. Beam dyeing is a technique where multiple yarns are wound side by side onto a single perforated beam. This can be a few hundred or even a few thousand yarns wound onto a single beam. Fabric or piece dyeing is the most cost efficient and highest productivity technique. Fabric dyeing machines include jet machines, dye becks, fabric beam, and jig dyeing machines. All of these machines as well as most of the yarn dyeing machines are batch or exhaust machines [12]. Some of the machines used in exhaustion method are shown in **Figures 1** and **2** [10, 15].

Advantages:

- Processing time, temperature and composition of the liquor (pH of the liquor, amount of electrolyte, auxiliary substances) can be adjusted as desired. Thus, the application speed (proper application of the dyestuff from the beginning) and the application amount (color fixation in dyeing) can be adjusted.
- The process can be easily intervened and additional toning can be made. Therefore, it is easier to attach the result than the impregnation method.
- It provides ease of operation as washing, bleaching, dyeing and finishing processes are carried out in the same machine.

Disadvantages:

- The most important disadvantage is that the liquor ratio is long, so the consumption of water, finishing chemicals and energy (required for both heating and moving the liquor) is so high.



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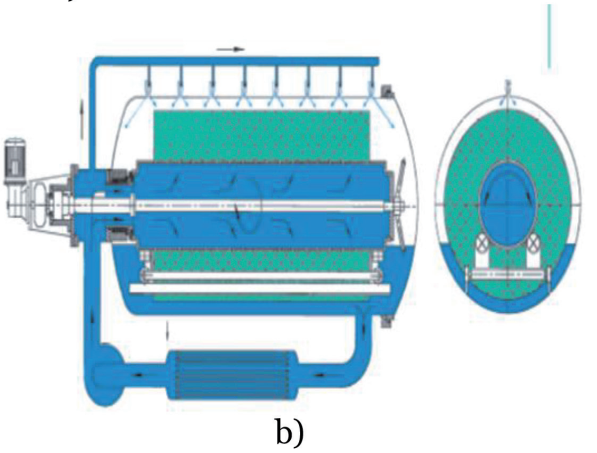
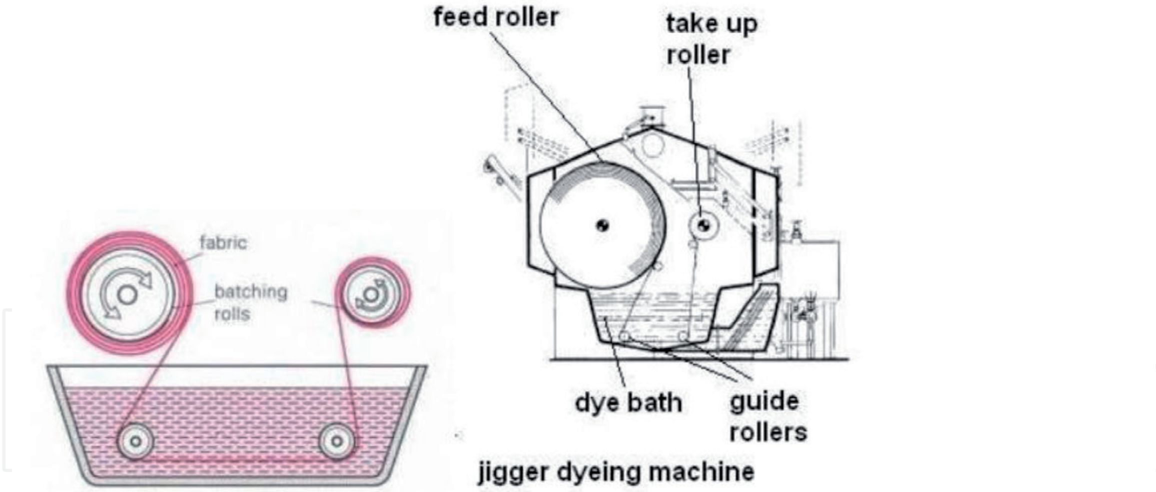


b)

Figure 1.
Exhausting process machines in textile finishing (a) winch dyeing (b) beam dyeing [13, 14].



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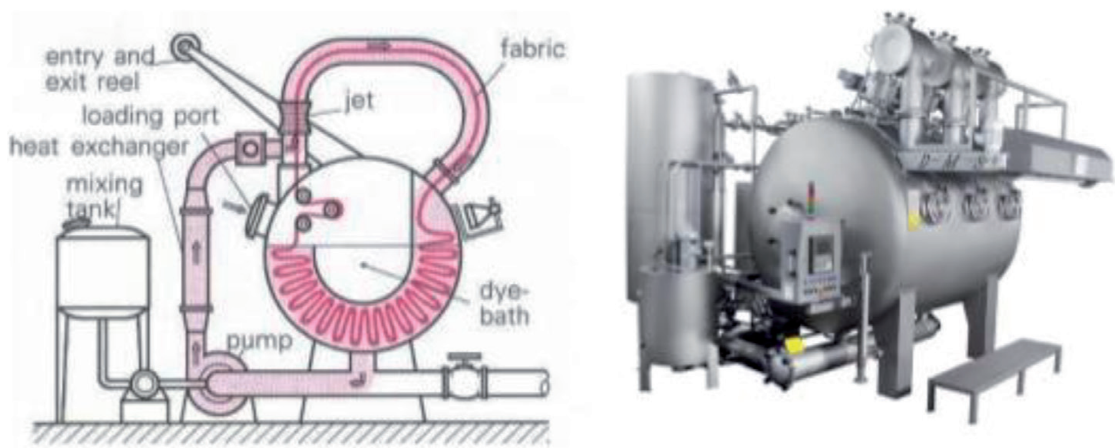

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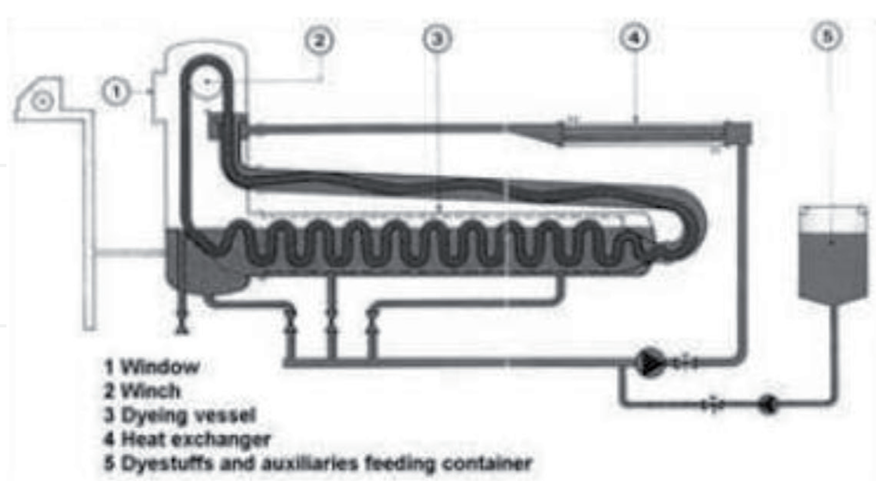


e)

Figure 2.
Exhausting process machines in textile finishing (c) jigger dyeing (d) jet dyeing (e) over-flow dyeing machines [13, 14].

- These are the discontinue methods that have long processing time (usually longer than 30 minutes).

- It requires a hand work and long time for operating the machine before application [5, 6, 8–10, 15].

2.2 Impregnation method

The application process, which is done by passing the textile product through the liquor in a bath within a short time (t < 30 seconds) and squeezing, is called impregnation (padding) method. After the fabric has been padded through the liquor and prior to being squeezed through the rollers of the padder, the liquor is distributed as follows: within the fibers; in the capillary regions-between the fibers; in the spaces between the yams; on the fabric surface [11, 15]. Two characteristics stand out in this method: short liquor ratio and short processing time. In impregnation method, it is important to not to use finishing chemicals that have affinities to the textile materials, or it should be at a very low level. As this is a continuous method, the concentration of the liquor absorbed by the product at the beginning should be same in the bath and at the end of the process. However, if finishing materials with high substantivity are used, the process results in with a tailing effect (when dyeing is done by padding method, gradual color change occurs along the fabric length because of the decrease in the concentration within time) [6, 9, 15]. Since most of the materials used in textile pretreatment do not show much substantivity towards fibers, unlike those used in dyeing, the most used application technique in these processes is impregnation. The types of impregnation machines work due to padding mechanism are shown in **Figure 3**. This method has also some disadvantages varied according to the types of the system, such as high concentration of finishing chemicals and long-time processing in pad-batch, tailing effect in pad-roll dyeing which is also labor intensive process, high energy consumption in pad-steam and necessity of an extra machine in pad-jig method which results in over costing investment. It should be also noted that high wet-pick-up ratios associated with the padding system are disadvantageous, not only because of the high thermal-drying and water consumption costs, but also because, during the evaporation of the liquor in thermal drying, the molecules of the applied substances tend to migrate from the inside to the outside of the fabric, leaving behind an uneven chemical distribution which leads to a decreased fabric durability of the functionality [5, 7, 15].

This method is divided into two as dry to wet impregnation and wet to wet impregnation. Since it is easier for a dry textile product to be absorbed in a bath containing finishing material (because the capillarity of the fibers is high due to its absorption ability), the dry-to-wet impregnation method works in shorter periods than wet-to-wet impregnation method. However; if a second wet finishing process is to be carried out after a wet finishing process, when the drying step is considered to be a very expensive intermediate process, the advantage of removing this part and saving energy indirectly will be achieved. Moreover, the risk of migration of the finishing chemicals which occur in drying process before the dyestuff/finishing agents are fixed on the fibers, could be prevented by removing this interim drying process in wet to wet impregnation [5, 15].

2.3 Transfer method

In this minimum (low wet-pick-up) application method made in special foulard, the fabric itself is not dipped into the bath. The liquor containing the finishing agent is taken by a rolling roller and transferred to the back surface of the fabric. That's why we could see this type of finishing systems under the name of "Lick/Kiss Roll Applicators" [19]. Transferring is an application method that can be applied with high viscosity finishing liquors. Excess liquor on the transfer roller or fabric is scraped off with the help of doctor blades. The **Figure 4** shows 4 different transfer systems, which differ in terms of the number of rollers, the location of the paddle

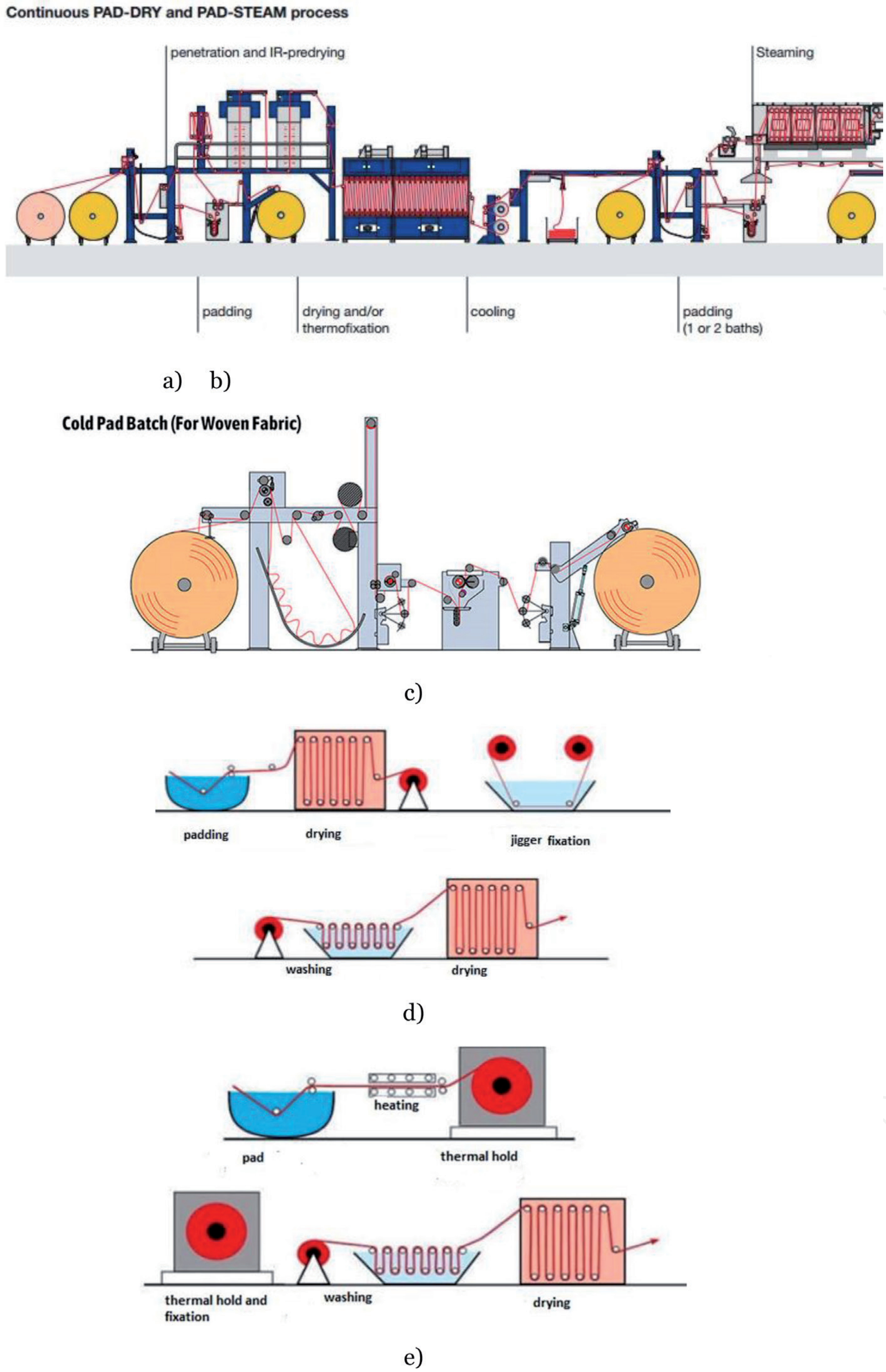


Figure 3.
Impregnation machines (a) pad-dry-cure (b) pad-steam (c) pad-batch (d) pad-jig (e) pad-roll [16–18].

and measurement techniques [6, 7, 9, 11, 15, 19]. The schematic representation of Triatex MA machine which uses on-line monitoring to control the wet pick-up values, has been shown in **Figure 4d**. The kiss roll rotational speed is automatically adjusted (with the help of β-rays measured by detectors) [15] relative to the fabric speed to maintain the desired wet pickup.

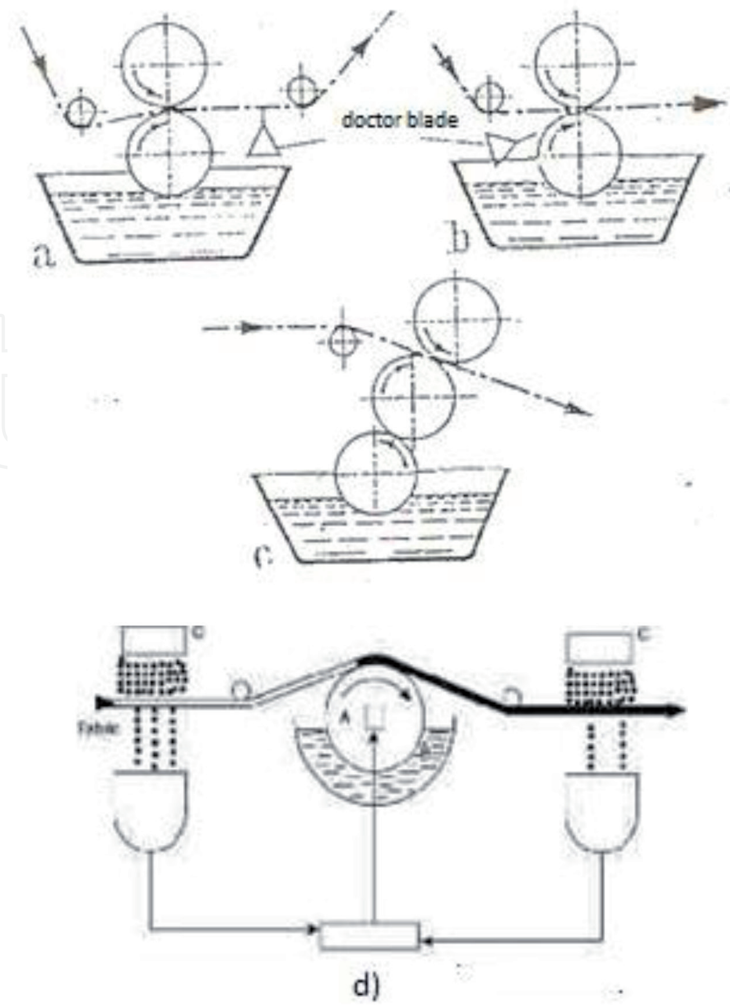


Figure 4.
Different types of transfer (with lick/kiss roll applicators) finishing methods (a) and (b) two-roller with doctor blade type (c) three-roller transfer type (d) Triatex MA [15, 19].

The amount of finishing agent transferred to the textile product is determined by following parameters; the structure of the transfer roller, condition of doctor blade and other rollers, viscosity of the liquid, the passing speed of the fabric and the rotation speed of the transfer roller. There are two big benefits of working with less liquor; firstly, energy savings as less water will need to be removed during subsequent drying and secondly, reduction of the risk of migration of dyestuffs or finishing substances that have not yet been fixed during drying. However; this method has also some disadvantages.

- The main problem in the operations of this method is the inconsistency of the formation of a smooth liquor on the transfer roller. This homogenous formation is not only dependent on the structure of the roller surface, but it's also closely related to the composition of the liquor.

- The second problem is the disability to ensure that the same amount of liquor continuously applied to the textile material [11, 15, 19].

2.4 Spraying method

Spraying method in finishing process has been known and applied on textiles for a long time however; it has not been improved much for many years because of some difficulties in conventional (nozzle) spraying machines mentioned below:

- It is difficult to apply the same amount of liquor all over the fabric continuously,

- Nozzles are frequently clogged, especially when working with viscous chemicals.

- A part of liquor sprayed in very fine particles is placed on other parts of the machine instead of the fabric, causes excessive pollution and unnecessary chemical loss.

Especially after the oil crisis in 1974, the spraying method has become updated with the increase in the importance of the application processes which has low wet-pick-up values. To overcome the difficulties in conventional spraying methods, indirect spray applications have been demonstrated by the Farmer Norton and Weko applicators. In these systems, the spray is generated by pumping the finishing solution by a proportioning pump from a well onto the center of a rapidly rotating set of spinning discs (Farmer Norton) or rotors (Weko) [7, 15, 19, 20]. In addition to have the main advantages of being in the minimum application system, spraying technology has some other advantages such as; being suitable for wet-to-wet applications, no tailing effect even if the chemicals have the affinity, ability to be applied on one or two sides of the fabric upon request [15, 20]. Weko Fluid application system has been shown in **Figure 5**.

2.5 Coating method

Finishing liquors with high viscosity can be applied directly to one side of the fabric. As a result of such application, a large amount of finishing material can be transferred to the surface of the material and this process is also called "coating", since the finishing agent mostly covers the surface of the material. The coating method is frequently used especially for producing artificial leather and waterproof finishing process. Multi-layered functional materials can be produced

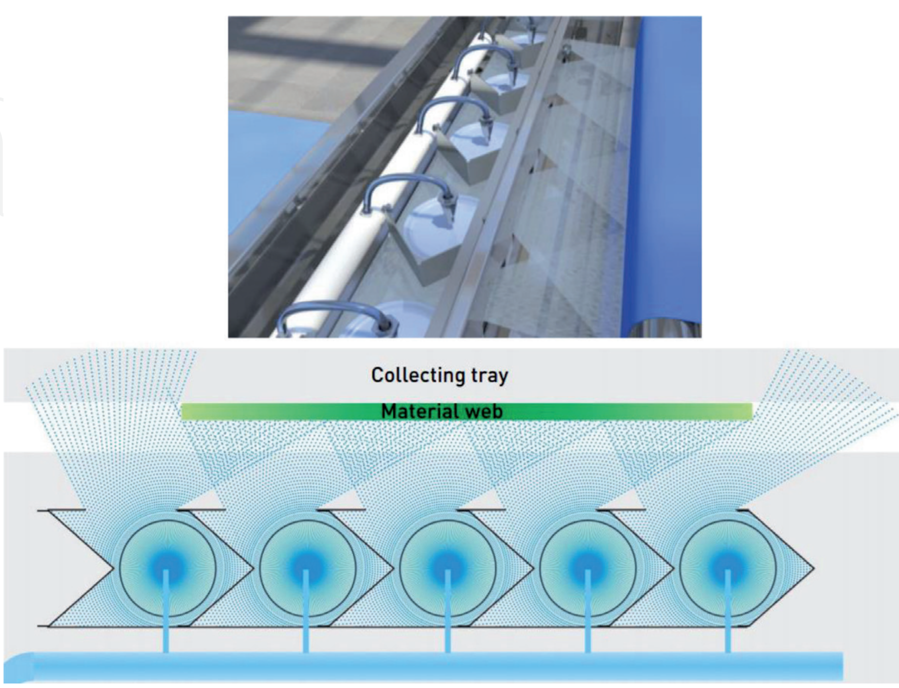


Figure 5.
WEKO-fluid application system [20].

with different coating methods including direct (directly coating on to the fabric) and indirect (using for exp. silicone paper during coating) system [15, 21–23]. In **Figure 6** illustrations of direct and indirect coating systems have been shown [23]. The basic mechanism of a direct coating method is spreading polymer on the textile material, in the form of thick liquid (viscous) or paste using a special knife called doctor blade [21]. The smoothness and the thickness of the applied layer are adjusted with the help of doctor blades.

In "blade on air" coating system, the fabric passing under the blade does not lean anywhere. Therefore, it is not possible to make thick and very smooth coatings with this type of coating. It is preferred for light coatings of loose woven fabrics. However; the coating material that passes to the other side of the fabric due to the loose texture, it contaminates the rubber band or roller under the blade and causes uneven coating. In "blade over the roller" system, the fabric that passes under the doctor blade is based on a rotating rubber or steel cylinder. The thickness of the layer applied in the coatings can be adjusted precisely. But on the other hand, since the cylinder cannot stretch; dust or fly can be trapped under the blade, causing soiling and forming drag lines [21].

There are some other coating processes used in the film and paper industries which require expensive equipment and which must be carried out on a large scale

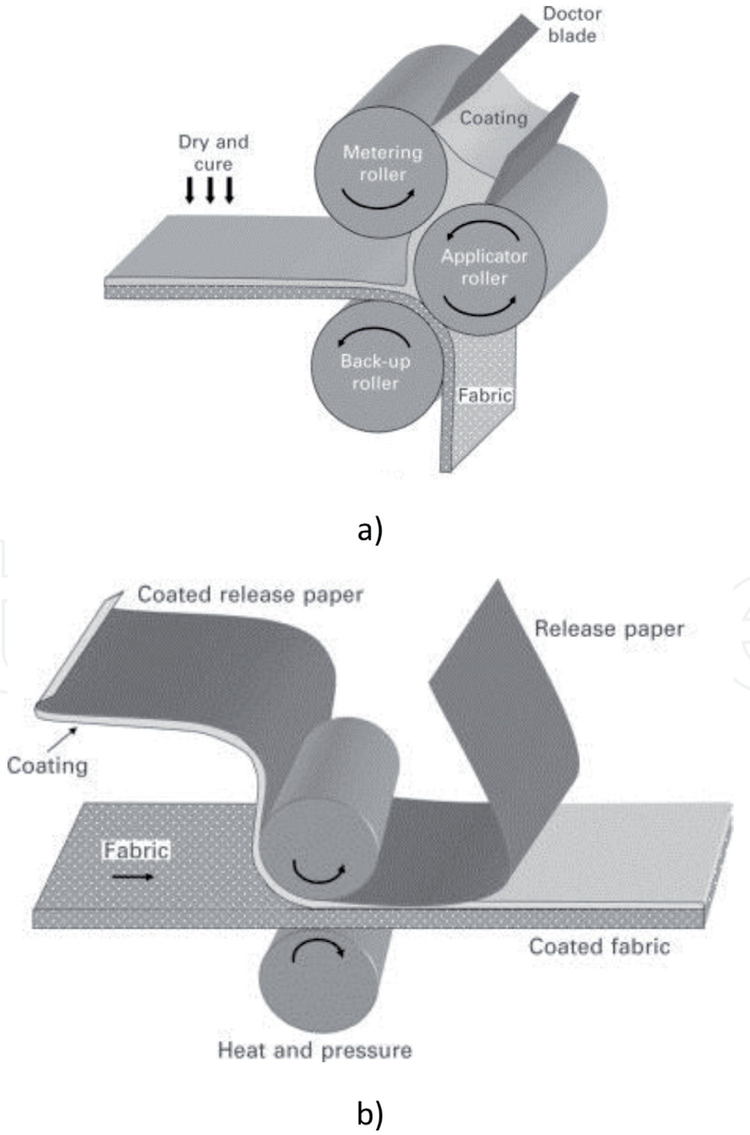


Figure 6.
(a) Direct coating system (three-roll coatings: Nip feed coating) (b) indirect coating system (transfer coating) [23].

to be commercially viable. Among these are powder coating, vacuum deposition, electrostatic deposition and sputtering techniques. It is possible, for example, to produce highly reflective surfaces by these methods, but a smooth continuous surface is required and fabrics may not be suitable [21, 22].

2.6 Foam application method

The most important and interesting development in the application of finishing agents to textile products in the mid-1970s is undoubtedly the application methods with foam. Machines that enable working with foams instead of aqueous solutions have been put on the market because of increased energy costs in the textile industries. However, the application studies with foam, which developed very rapidly in the beginning, have entered a pause and had no significant improvement until 2010 [24].

Foam is a microheterogeneous colloidal mixture, short or long-lasting a metastable system in which the surface area is increased nearly 1000 times by inflating a liquid with a suitable gas (air), and therefore contains less liquid. Foam is obtained by dispersing the air in water as fine particles with the help of surfactants. If a surfactant is dissolved in aqueous solution and air bubbles are present in this solution, then a surfactant film covers the air bubbles. Air bubbles move towards the upper surface of the liquid which covered with a tenside film. Thereby, a second tenside film is formed around the upward air bubbles (**Figure 7**) In this way, the air bubble in which the liquid is located between the two tenside films surrounding, called a "foam cell" [7, 15, 24, 25].

There are many types of foam application such as; open foam method (Horizontal pad foam, Knife-roll-over foam, Autofoam systems), offset open foam methods (Küsters Janus contact roller system and Monforts vacuum drum system), closed foam methods (FFT Foam Finishing Technology-Gaston County Dyeing Machine, CFS Chemical Foam System-Gaston System, Stork rotary screen foam applicator and Stork CFT Coating and Finishing Technology) have been shown in **Figures 8-10** [24, 29, 30]. As seen in the figures, there have been much improvement in the profiles of foam applicators in time in order to prevent the problems such as non-uniform and uneven applications during processes. The case in point can be the improvement of CFS parabolic profile which has been developed to solve "dead foam" issue occurred in FFT. With the help of parabolic chamber, equal distance paths are covered from the point of foam inlet to the fabric surface so that the problem of wet and unfoamed parts occurred partly in FFT foamed fabrics have been solved [24, 29].

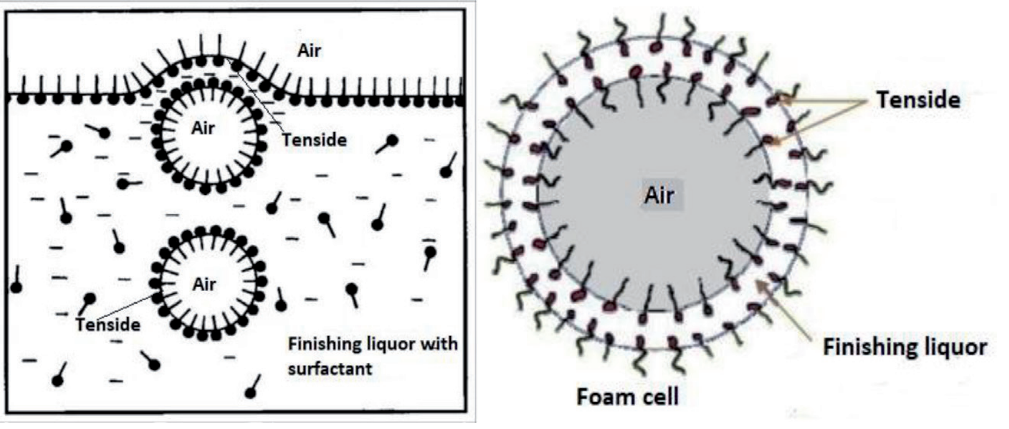


Figure 7.
Formation of a foam cell.

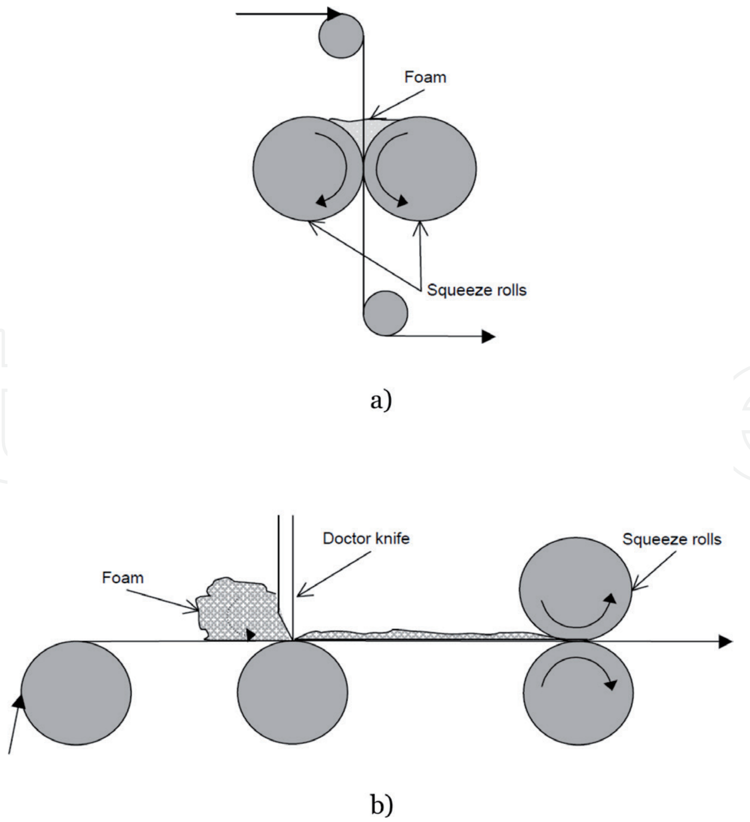


Figure 8.
Types of foam application (a) horizontal pad foam (b) knife-roll-over foam [24, 26–28].

For an effective foam application process, the followings should be taken into consideration:

- The foam should not be collapsed during the time between it is taken from the foam generator and transferred to the fabric.

- On the other hand, when the foam reaches out the textile product, it should collapse into the fabric as quickly as possible. Foam stability constitutes an important place in foam applications. Very stable foams play role in decreasing the penetration efficiency into the fabric whereas unstable foams cause uneven applications because of collapsing before the application. Therefore, foam cell should be in semi-stable form.

- The foam and the tenside used in the application must have good compatibility with other chemical substances in the bath.

- The foam to be used in a finishing process should always has the same form and the same concentration.

- Another important point in foam application is that the foams should not have much water. If the foam that does not contain much water, it is transferred directly onto the fabric surface moving perpendicularly without spreading around the fabric surface. On the other hand, when the conventional finishing liquors first penetrated to the fabric, they spread parallel to the fabric surface by capillarity effect. For this reason, in conventional finishing applications such as in padding methods non-functional caked chemical residuals remained at the fibers intersections cause uneven application and nonhomogeneous penetration [15, 27].

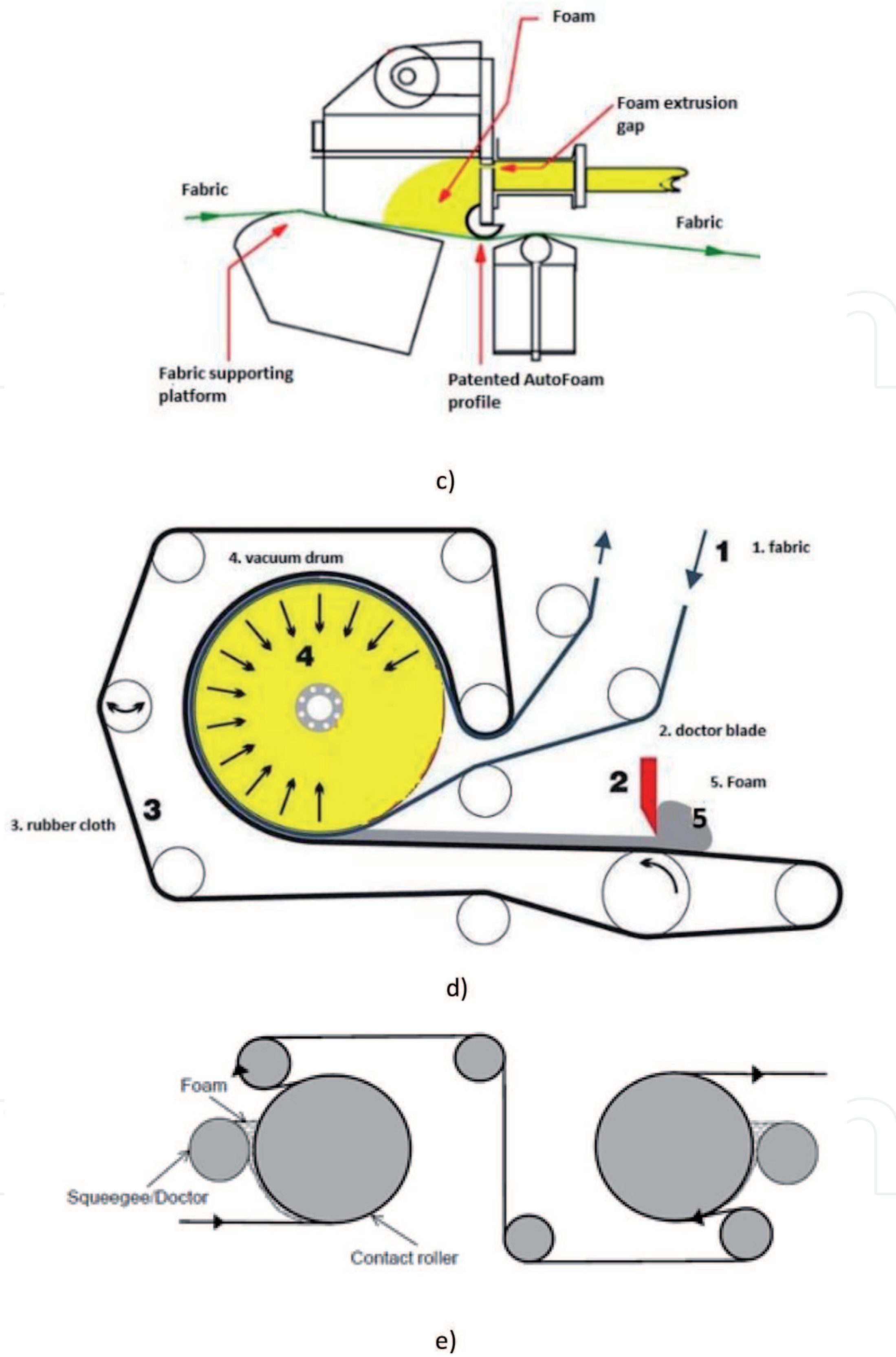
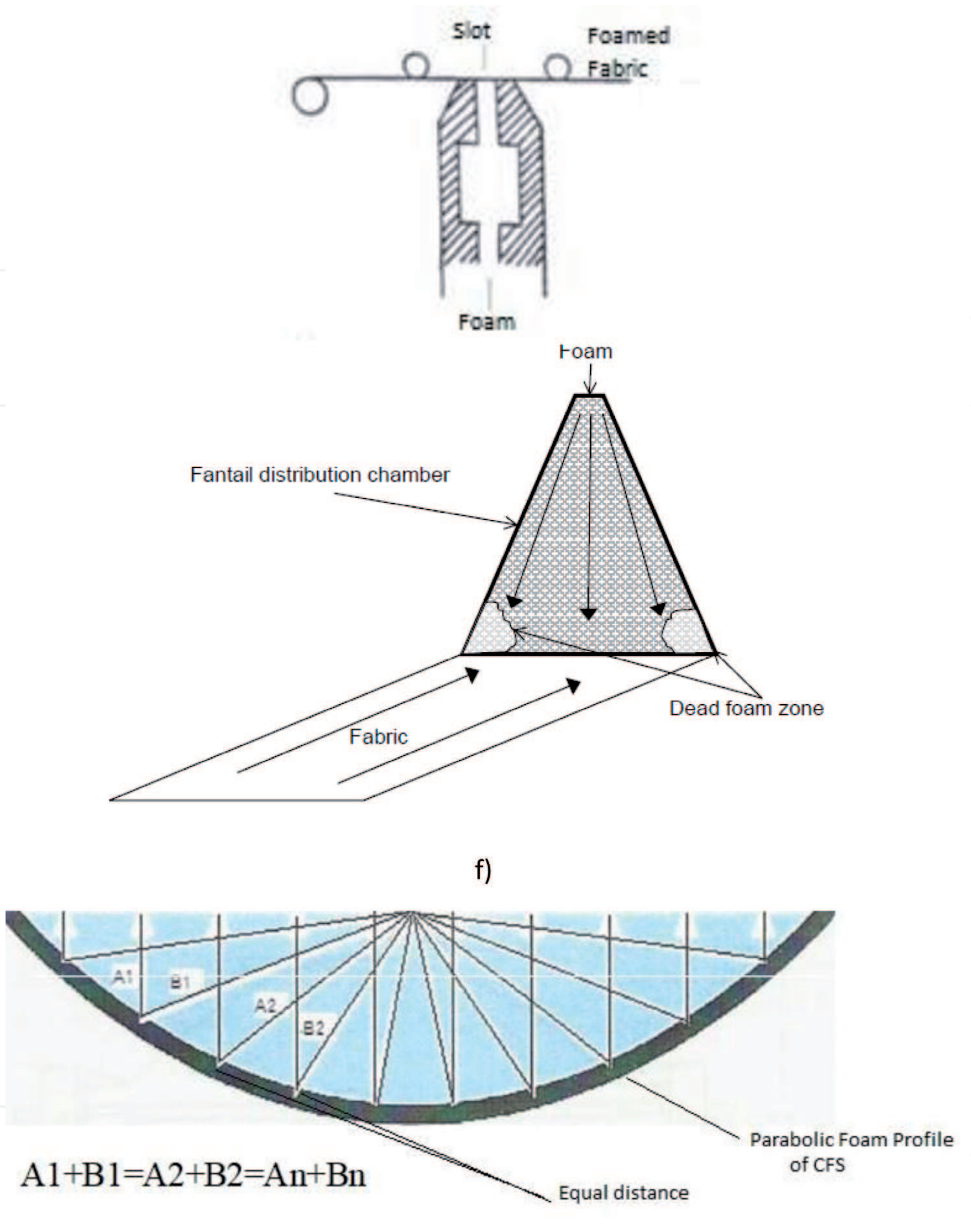


Figure 9.
Types of foam application (c) autofoam systems (d) Monforts vacuum drum system (e) Küsters Janus contact roller system [24, 26–28].

2.6.1 Advantages of foam application

Foam finishing is a versatile application system which could be very effective for bleaching, dyeing and varied finishing processes. It can be also used to apply different applications to the face and back side of the fabric in a single pass with



g)

Figure 10.
Types of foam application (f) foam finishing technology (FFT) (g) chemical foaming system (CFS) [24, 26–28].

dual-applicators. Multifunctional fabrics with increased durability against repeated washing and drying processes could be produced. As reported in the literature [24] that many combinations of functionalities such as face side flame retardant and water repellent whereas antibacterial back side of textile materials could be provided via foam finishing application. The most important advantage of this system is providing significant decrease in water consumption (up to 80%) due its lower wet-pick-up system. For cotton-rich fabrics, the wet pickup in foam finishing is typically between 15% and 35%, depending on the process, compared with 60%

to 100% for a conventional pad application [27, 29, 30]. For synthetic fabrics, wet pick up ratio of foam application is in the range of 3–10% whereas it is 35–60% in conventional padding. Moreover, the energy consumed for heating and venting the air is significantly decreased due to lower wet-pick-up values. This reduction in time needed for pre-drying step (could be eliminated), also minimizes the migration of the chemicals. Since the amount of liquor taken is small in foam finishing, excessive swelling of the fibers is not possible. Since the fibers do not swell and the capillary channels do not expand too much, the transferred chemical substance is not carried to the surface with water during drying and remains where it is transferred. This is particularly effective in preventing the reduction of the abrasion resistance in the wrinkle recovery finishing. Since migration, that is, the accumulation of the chemical substance on the surface more than necessary during drying, is effective in the decrease in friction resistance. Foam application also potentially results in less waste water pollution than with traditional application methods. On the contrary of an aqueous pad system, the small liquor volumes required for foam application result in less waste during a changeover [15, 24, 27, 29, 31–34].

Updated versions of foam application systems has offered better solutions to the basic problems encountered with the other low-add-on systems. The main problem of the low-add-on systems is the difficulty of distributing a relatively small quantity of liquor uniformly over a large surface of fabric, especially on hydrophilic fibers. In the case of low-add-on expression systems, a basic limitation is the inability to achieve wet-pick-up levels below the critical application value of the component fibers [7]. When compared to conventional methods, foam finishing provides homogeneous and effective chemical applications via controlled, uniform and repeatable foam formations.

2.6.2 Chemical foaming system (CFS)

If CFS foam machine is examined, it could be clearly seen that uniform and homogenous applications are achieved via performing correct systematic on the distance between the foam generator and applicator.

As shown in the **Figure 11**, the foam diameter increases as the foam formed in the CFS foam generator is transferred from high pressure to the low pressure on the way to the foam applicator. The pressure gradually decreases on the fabric surface and the foam penetrates the fabric. The distance between the foam generator and its applicator is critical for uniform foam formation.

DG: Initially, the radius of the foam produced in the foam generator.

DA: The radius of the foam being transferred from the foam generator to the foam applicator.

DB: The radius of the foam at the foam applicator just before it penetrates to the fabric.

WG: Initially, the area covered by the liquid contained in the foam produced in the foam generator.

WA: The area covered by the liquid in the foam being transferred from the foam generator to the foam applicator.

WB: The area covered by the liquid in the foam just before it penetrates into the fabric, at the foam applicator.

Before the transfer process starts, the state between these parameters is $WG > WA > WB$ and $DG < DA < DB$, while these equations are reversed as the pressure decreases gradually, and $WG < WA < WB$ and $DG > DA > DB$ becomes. Therefore, on the foam applicator, penetration to the fabric takes place evenly with maximum radius and minimum liquid area of the foam [27].

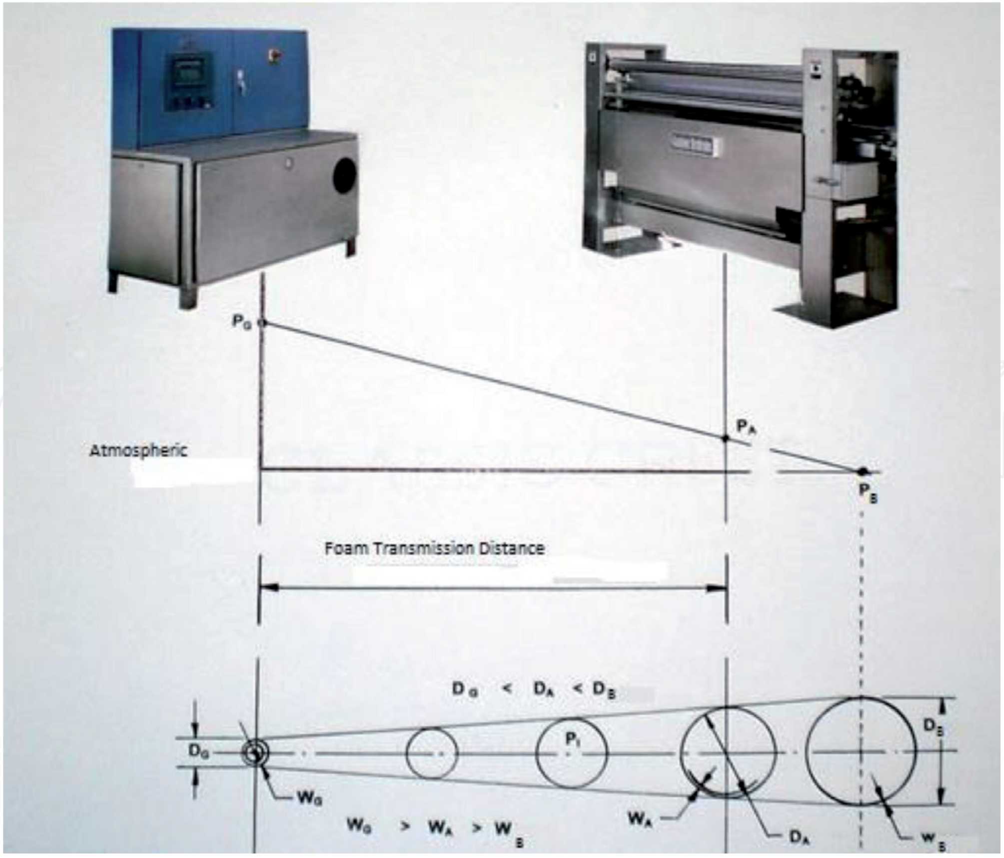


Figure 11.
Chemical foaming system (CFS) [27].

3. Conclusion

Considering the finishing methods used in the textile industry in general, conventional impregnation method is commonly used in the industry due to the low affinity of the chemicals used in the finishing processes. However, it has disadvantages such as high water and energy consumption, inability to apply different functionalities to face and back sides of the material and significant waste load. Extraction method is not included among the preferred methods because the chemicals used have affinity to the fabric, the operation times are long and the amount of water consumed is very high due to the long liquor ratio. Apart from these methods, transfer and coating methods are also available. Transfer methods with various types such as roller transfer or with doctor blades takes place in the minimum application methods. Likewise coating methods is in the low-liquor finishing applications with the types of blade coating, calendar coating, transfer and printing technique. However, both transfer and coating methods are not suitable for low viscosity chemicals. In coating and transferring methods, the effectivity of the application is directly related to the viscosity of the finishing agents, the construction and surface structure of textile material, production method of the material (woven, non-woven or knitted), weight of the textile, speed of the finishing method etc. So, it could be noted that they are not very flexible application techniques in a view of finishing agents and textile materials. Even if the direct spraying method had some problems in the past such as clogging of nozzles or excessive pollution on the machine, with the use of indirect systems such as discs or rotors, it has been much more improved. When the history of the foam application is examined, it could be clearly noticed that significant improvements have been carried out by time in order to make functional or multifunctional (via using dual-applicators) textiles via uniform applications (with developed applicator profiles) which provides reduction in water and energy consumption. Apart from these, there are various lamination techniques that can be used to obtain multifunctionality however; since the lamination process is based on the principle of combining fabric and polymer layers to form a composite material, any factor that prevents adhesion between the structures, low heat resistance of the materials or no resistivity for water and moisture can cause problems during applications.

Apart from these methods, there is also environmentally friendly techniques such as plasma technology, which is used in the textile industry and academic pilot studies, and gives functionality to the fabric with partly ionized gas or monomers without using water [35–37]. With this technology many researches have been carried out to provide functional textiles such as antibacterial cotton fabric supported by silver nanoparticules [38], water repellent and antimicrobial cotton/polyester blend [39], anti-bacterial and anti-static polyester fabric [40]. However, in this technology, the vacuum plasma method, which is quite effective, is a discontinuous method and could not be industrialized because it allows a very low size in terms of fabric length and width. The atmospheric plasma method, which is suitable for industrial use as the operating dimensions, is not as effective as vacuum plasma on porous textile surfaces. Microencapsulation technique, is also one of the effective methods used in textile applications. Microencapsulation technology involves the process by which small particles, mostly bioactive, are encapsulated in a wall consisting of a heterogeneous or homologous polymer matrix, which forms a complex known as a microcapsule [41, 42]. Microencapsulation helps to improve functional textile products such as fabrics with durable fragrances, UV-ray absorbing shirts, thermo-regulation vehicle seats, thermo-changeable dyed apparels, vitamin loaded fabrics as cosmototextiles or military uniforms with microcapsulated insecticides [42]. However, in order to transfer performed microcapsules onto the textile material, the capsulation method is continued with a conventional finishing method frequently (mostly padding) so that two-step applications are carried out with no significant reduction in water and energy consumption. Sol–gel technology, which is a method that can obtain macromolecules by taking advantage of the growth and development of polymers in a solvent, can also be an effective alternative in terms of giving functionality to textile materials. There have been lots of studies on sol–gel functionality such as self-cleaning superhydrophobic films [43], flame retardant and hydrophobic coatings on cotton fabrics [44], hydrophilic, antistatic and antimicrobial cotton and polyester fabrics [45]. However, it should be noted that the requirement of using solvents brings environmental threats and applying some special polymers increase input costs [46]. Nano-technology seems to be a significant alternative for achieving functional and multifunctional textile materials [35] however; in some cases, there have been still some issues of industrialization of nanoparticles because of producing them only in laboratory scale experiments. Studies about using liposomes in dyeing processes [47–49] photocatalytic reactions for bleaching process [50, 51] and layer-by-layer self-assembly technique for producing multifunctional multilayers [52, 53] have also been taken place in the literature but there has been no scientific clue reported in the literature for industrialization of these methods in textile manufactories.

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